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August 5, 2011

Ms. Brooke Doi
Shea Homes
1250 Corona Pointe Court, Suite 600
Corona, California 92787

Subject: Groundborne Vibration Impact Analysis, Shea Baker Ranch Project, City of Lake Forest, California

Dear Ms. Doi:

LSA Associates, Inc. (LSA) prepared a noise impact study report (July 2011) for the proposed Shea Baker Ranch project in the City of Lake Forest, California (City) for Shea Homes. The following vibration impact analysis was conducted to evaluate whether any potential vibration impact would occur to existing and future noise-sensitive receptors adjacent to the project's active construction areas. This analysis was prepared in compliance with NM 3.10-2 of the Program Environmental Impact Report for the Opportunity Study Area, which requires a site-specific analysis of groundborne vibration.

Introduction to Vibration

Vibration refers to groundborne noise and perceptible motion. Groundborne vibration is almost exclusively a concern inside buildings and is rarely perceived as a problem outdoors, where the motion may be discernable, but without the effects associated with the shaking of a building, there is less adverse reaction.

Vibration energy propagates from a source through intervening soil and rock layers to the foundations of nearby buildings. The vibration then propagates from the foundation throughout the remainder of the structure. Building vibration may be perceived by the occupants as motion of building surfaces, rattling of items on shelves or hanging on walls, or a low-frequency rumbling noise. The rumbling noise is caused by the vibrating walls, floors, and ceilings radiating sound waves. Groundborne vibration is usually measured in terms of vibration velocity, either the root-mean-square (rms) velocity or peak particle velocity (PPV). Rms is best for characterizing human response to building vibration, and PPV is used to characterize potential for damage.

Annoyance from vibration often occurs when the vibration exceeds the threshold of perception by 10 decibels or less. This is an order of magnitude below the damage threshold for normal buildings. Ground vibrations from construction activities do not often reach the levels that can damage structures, but they can achieve the audible and feelable ranges in buildings very close to the site. Problems with groundborne vibration from construction sources are usually localized to areas within about 100 feet (ft) from the vibration source.

Typical sources of groundborne vibration are construction activities (e.g., blasting, pile-driving, and operating heavy-duty earth-moving equipment), steel-wheeled trains, and occasional traffic on rough roads. Problems with groundborne vibration and noise from these sources are usually localized to areas within approximately 100 ft from the vibration source although there are examples of groundborne vibration causing interference out to distances greater than 200 ft (Federal Transit Administration [FTA] 2006). When roadways are smooth, vibration from traffic, even heavy trucks, is rarely perceptible. It is assumed for most projects that the roadway surface will be smooth enough that groundborne vibration from street traffic will not exceed the impact criteria; however, construction of the project could result in groundborne vibration that could be perceptible and annoying. Groundborne noise is not likely to be a problem because noise arriving via the normal airborne path usually will be greater than groundborne noise.

Groundborne vibration has the potential to disturb people as well as to damage buildings. Groundborne vibration is usually measured in terms of vibration velocity, either the rms velocity or PPV. The rms is best for characterizing human response to building vibration, and PPV is used to characterize potential for damage.

Factors that influence groundborne vibration and noise include the following:

- **Vibration Source:** Vehicle suspension, wheel types and condition, track/roadway surface, track support system, speed, transit structure, and depth of vibration source
- **Vibration Path:** Soil type, rock layers, soil layering, depth to water table, and frost depth
- **Vibration Receiver:** Foundation type, building construction, and acoustical absorption

Among the factors listed above, there are significant differences in the vibration characteristics when the source is underground rather than at the ground surface. In addition, soil conditions are known to have a strong influence on the levels of groundborne vibration. Among the most important factors are the stiffness and internal damping of the soil, and the depth to bedrock.

Construction Vibration

Construction-related vibration generated by construction equipment can result in varying degrees of ground vibration, depending on the equipment. Operation of construction equipment causes ground vibrations that spread through the ground and diminish in strength with distance. Buildings situated on soil near the active construction area respond to these vibrations that range from no perception to low rumbling sounds with perceptible vibrations and slight damage at the highest vibration levels. Typically, construction-related vibrations do not reach vibration levels that would damage nearby structures. However, old and fragile structures would require special consideration to avoid damage.

Tables A and B, from the California Department of Transportation (Caltrans) Transportation- and Construction-Induced Vibration Guidance Manual (Caltrans, June 2004), show vibration damage potential threshold criteria and vibration annoyance potential criteria, respectively. Table A indicates that the vibration damage threshold is 0.5 PPV (inches per second [in/sec]) for historic and some old buildings and older residential structures, and 0.2 PPV (in/sec) for fragile buildings. For extremely fragile historic buildings, ruins, and ancient monuments, the threshold is 0.12 PPV (in/sec) from a transient source. However, for new residential structures and modern commercial buildings, the vibration damage threshold is 1.0 PPV and 2.0 PPV, respectively. Tables A and B were used to evaluate short-term, construction-related groundborne vibration.

Table A: Guideline Vibration Potential Threshold Criteria

Structure and Condition	Maximum PPV (in/sec)	
	Transient Sources[1]	Continuous/Frequent Intermittent Sources[2]
Extremely fragile historic buildings, ruins, ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5

Source: Caltrans Transportation- and Construction-Induced Vibration Guidance Manual, June 2004.
[1] Transient sources create a single, isolated vibration event, such as blasting or drop balls.
[2] Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.
in/sec = inches per second
PPV = peak particle velocity (VdB)

Table B: Guideline Vibration Annoyance Potential Criteria

Human Response	Maximum PPV (in/sec)	
	Transient Sources[1]	Continuous/Frequent Intermittent Sources[2]
Barely perceptible	0.04	0.01
Distinctly perceptible	0.25	0.04
Strongly perceptible	0.9	0.10
Severe	2.0	0.4

Source: Caltrans Transportation- and Construction-Induced Vibration Guidance Manual, June 2004.
[1] Transient sources create a single, isolated vibration event, such as blasting or drop balls.
[2] Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.
in/sec = inches per second
PPV = peak particle velocity

Similarly, Table C, from the FTA's Vibration Source Levels for Construction Equipment in Transit Noise and Vibration Impact Assessment (FTA, May 2006), shows that except for buildings extremely susceptible to vibration damage, most structures would not have any building damage until the vibration level increases to 94 vibration velocity decibels (VdB) or higher.

The proposed project may require the use of large bulldozers and trucks for the construction of on-site buildings. Based on Table 12-2, Vibration Source Levels for Construction Equipment in Transit Noise and Vibration Impact Assessment (FTA, May 2006, and shown here in Table D), large bulldozers typically generate 0.089 inches per second (in/sec) PPV or 87 VdB at 25 ft. Large loaded trucks typically generate 0.076 PPV or 86 VdB at 25 ft. Based on the Caltrans Transportation Related Earthborne Vibration, Technical Advisory (Rudy Hendricks, July 24, 1992), the vibration level at 50 ft is approximately 6 VdB lower than the vibration level at 25 ft. Vibration at 100 ft from the source is more than 6 VdB lower than the vibration level at 50 ft, or more than 12 VdB lower than the vibration

Table C: Construction Vibration Damage Criteria

Building Category	PPV (in/sec)	Approximate L_v (VdB)
I. Reinforced concrete, steel or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry buildings	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

Source: Transit Noise and Vibration Impact Assessment, May 2006.
in/sec = inches per second
PPV = peak particle velocity
L_v = velocity level in decibels

Table D: Vibration Source Amplitudes for Construction Equipment

Equipment	Reference PPV at 25 ft (in/sec)	Approximate L_v At 25 ft (VdB)
Pile Driver (impact), typical	0.644	104
Pile Driver (sonic), typical	0.170	93
Vibratory roller	0.210	94
Large bulldozer	0.089	87
Caisson drilling	0.089	87
Loaded trucks	0.076	86
Jackhammer	0.035	79
Small bulldozer	0.003	58
Crack-and-seat operations	2.4	ND

Sources: Federal Transit Administration 2006 (except Hanson 2001 for vibratory rollers) and Caltrans 2000 for crack-and-seat-operations.
ft = feet
in/sec = inches per second
PPV = peak particle velocity
ND = No data
VdB = vibration velocity decibels

level at 25 ft. Therefore, large bulldozers would potentially result in 81 VdB at 50 ft and 75 VdB at 100 ft. Loaded trucks would potentially result in 80 VdB at 50 ft and 74 VdB at 100 ft.

Based on the soils study report (Pacific Soils Engineering, Inc., November 5, 2002) for Tentative Tract Map No. 16466, Baker Ranch, City of Lake Forest, the surficial units on site include engineered and uncontrolled artificial fill, topsoil, colluvium/alluvium, and Terrace Deposits. The character of the on-site soil is partially a function of the underlying parent material. Soil developed on the Terrace Deposits and Capistrano Formation is predominantly silty to clayey sands. Sandy clays are presently developed upon the Monterey Formation. The alluvium/colluvium consists of silty sands and clayey sands. The Terrace Deposits are typically tan/reddish brown silty/clayey sands with occasional pebble and cobble lenses.

Experience with groundborne vibration indicates that vibration propagation is more efficient in stiff clay soils than in loose sandy soils, and shallow rock seems to concentrate the vibration energy close to the surface and can result in groundborne vibration problems at large distances from the road. Factors such as layering of the soil and depth to water table can have significant effects on the propagation of groundborne vibration. Soft, loose, sandy soils tend to attenuate more vibration energy than hard, rocky materials. Vibration propagation through groundwater is more efficient than through sandy soils.

As a worst-case scenario, potential vibration impacts are evaluated for large bulldozers and trucks to be used during construction of the on-site structures. Because the upper layers of the soil in the project area are mostly sandy/silty soil, the drop-off rate for the sandy/silty soil is used to estimate the vibration levels.

Off-Site Construction Vibration Impacts. There are no existing residences immediately adjacent to the project site. The adjacent commercial buildings are at least 50 ft from the project construction area. Based on Table D, large bulldozers would generate a vibration level of 0.089 PPV (in/sec) or 87 VdB at 25 ft. At a distance of 50 ft or more, the vibration level would be lower and would not exceed the 2.0 PPV maximum threshold for commercial buildings. Based on Table B, the vibration level from large bulldozers would also not exceed the 0.1 PPV strongly perceptible threshold from continuous/frequent intermittent sources. Similarly, it would not expose the adjacent commercial buildings to vibration levels from on-site construction equipment (large bulldozers and loaded trucks) that exceed 81 VdB at a distance of 50 ft. This range of the vibration levels is lower than the 94 VdB construction vibration damage criteria for the commercial buildings, as shown in Table C. Therefore, existing off-site receptors at the adjacent commercial uses may be exposed to distinctly perceptible vibration levels from on-site project construction, but the vibration would not reach the levels that are strongly perceptible to the workers and would not result in any structural damage.

On-Site Construction Vibration Impacts. In addition, based on the project's proposed phasing, residences in the first few phases (Phase 1A or 2) may be exposed to vibration impacts associated with building construction in later phases (Phases 2 or 3A). The residential buildings in earlier phases are at least 50 ft from the later phase project construction area. Based on Table D, large bulldozers would generate a vibration level of 0.089 PPV (in/sec) or 87 VdB at 25 ft. At a distance of 50 ft or more, the vibration level would be lower and would not exceed the 1.0 PPV maximum threshold for new residential buildings. Similarly, the earlier phase residential buildings would not be exposed to vibration levels from later phase on-site construction equipment (large bulldozers and loaded trucks) that exceed 81 VdB at a distance of 50 ft. This range of the vibration levels is lower than the 94 VdB construction vibration damage criteria for the new residential buildings, as shown in Table C. Therefore, future on-site receptors at the residential areas in earlier phases may be exposed to distinctly perceptible vibration levels from on-site project construction in later phases, but the vibration would not reach the levels that are strongly perceptible by the residents and would not result in any structural damage.

Because Phases 1B and 3B are separated with the other phases by Rancho Parkway and Alton Parkway, respectively, that are more than 50 ft wide, vibration associated with construction activity in

Phases 1B and 3B would result in vibration levels lower than those discussed above and is not expected to adversely affect residences in other phases (Phases 1A, 2, and 3A), and vice versa.

Long-Term Operational Impact

Vehicular Traffic. Because the rubber tires and suspension systems of trucks and other on-road vehicles isolate vibration, they don’t usually cause groundborne noise or vibration problems. When on-road vehicles cause effects such as rattling windows, the source is almost always airborne noise. Groundborne vibrations are associated mostly with passenger vehicles and trucks traveling on poor roadway conditions such as potholes, bumps, expansion joints, or other discontinuities in the road surface. Smoothing the bumps or filling the potholes will usually solve the problems. As the project will construct new roads within the project boundary, there will be no potholes, bumps, expansion joints, or other discontinuities in the road surface that would generate groundborne vibration or noise impacts from vehicular traffic traveling on on-site streets.

Stationary Sources. Because the proposed project does not propose any facility or activity that would result in significant vibration on the project site, no long-term operational vibration impacts would occur from stationary sources.

Conclusion

Based on the above analysis, vibration from construction activities associated with the proposed Shea Baker Ranch project, including those from large bulldozers or loaded trucks, would not result in substantial vibration levels at the existing commercial structures adjacent to the project site. These vibration levels would not reach the 2.0 in/sec PPV threshold shown in Table A for commercial buildings or the 1.0 in/sec PPV threshold for new residential buildings recommended by Caltrans. Similarly, although the on-site construction vibration potentially could result in distinctly perceptible vibration levels at the existing commercial uses or at residences in earlier phases, the vibration level would not be sufficiently perceptible to cause annoyance. In addition, groundborne vibration from on-road vehicles suing the off-site streets would not result in any measureable changes in vibration level compared to the existing conditions and would not result in any vibration levels that would damage buildings. No substantial vibration impacts would occur as a result of the proposed project.

Please contact me at (949) 553-0666 if you have any questions regarding this report.

Sincerely,

LSA ASSOCIATES, INC.

Tungchen Chung

Tung-chen Chung, Ph.D.
Principal

REFERENCES

Caltrans, January 23, 2004. California Department of Transportation. *Transportation-Related Earthborne Vibrations, Technical Advisory, Vibration TAV-04-01-R0201s*.

Caltrans, June 2004, California Department of Transportation, *Transportation- and Construction-Induced Vibration Guidance Manual.*

Federal Transit Administration, May 2006, *Transit Noise and Vibration Impact Assessment. FTA-VA-90-1003-06.*

Pacific Soils Engineering, Inc. November 5, 2002, *Geotechnical Review of 100-Scale Tentative Tract Map NO. 16466, Baker Ranch, City of Lake Forest, County of Orange, California.*